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AR-006-867

DISRUPTIVE PATTERN PRINTED CANVAS FOR ARMY VEHICLES

G. SOUTHWELL, J. STEWART AND A. de FOREST

MRL-TN-606

MATERIALS RESEARCH LABORATORY
DSTO

Disruptive Pattern Printed Canvas for Army Vehicles

Gordon Southwell, Janine Stewart and Albert deForest

MRL Technical Note
MRL-TN-606

Abstract

A design for the disruptive pattern printing of canvas used for canopies on army vehicles was developed by DSTO MRL Melbourne. The effect of exposure to a variety of climatic conditions on print durability and fabric properties was determined.

MATERIALS RESEARCH LABORATORY

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(MRL-TN-606)

CORRIGENDA

p. 19: Appendix C, Colour Fastness Table

Column headed Original S, line 1 and line 3:
60 DK should be 6 DK

Column headed Original M, line 1 and line 3:
60 DK should be 6 DK

Column headed Results Weatherometer S110
line 7 and line 9:
40 DK should be 4 DK

Column headed Weatherometer M110 line 7 and line 9:
30 DK should be 3 DK

Disruptive Pattern Printed Canvas for Army Vehicles

1. Introduction

In 1987, The Office of Director General of Operations and Plans (DGOP) released a draft Army Office Staff Instruction (AOSI) for the Disruptive Pattern Painting (DPP) of Army equipment. The policy covered both existing and new equipment including the disruptive pattern for canvas vehicle canopies.

In practice it was found that the vehicle disruptive pattern could be extended from the body of the vehicle to include the canvas canopy using coatings which matched the camouflage paint colours of the vehicle. Special reproofing paints in the three camouflage colours, olive, black and tan were developed for use on existing vehicle covers. These paints were capable of being applied by either roller, brush or spray painting with all equipment being water cleanable. An additional advantage of these paints was that the acrylic base covered small holes and other imperfections in the canvas thus extending its service life. The major disadvantage was that each vehicle type had a different camouflage pattern, making it impossible to produce a commercially printed design that matched the pattern for each individual vehicle.

To overcome this problem, this laboratory developed a disruptive printed pattern design for use on all canvas vehicle canopies which subsequently was given provisional endorsement by DGOP. The colours were black and tan printed on green canvas and the design was originally for a vertical repeat of 1736 mm on a cloth width of 1830 mm. Later, the pattern was enlarged to a vertical repeat of 2320 mm which was the largest screen size available. The colour separation design for the two sizes of screens is given in Appendix A and the printed pattern as applied to a canopy of a vehicle is shown in Figure 1. Two local canvas manufacturers supplied a limited quantity of camouflage printed canvas under Army funding and the suitability of the canvas materials was determined by laboratory evaluation before and after exposure trials. Surplus canvas was supplied to "Project Perentie" and made into vehicle canopies for the new Perentie vehicles, currently in operation in northern Queensland. This report details the results of the laboratory evaluation on the printed canvas before and after exposure trials and its suitability for use in vehicle canopies.

Future work will compare the field performance of the vehicle canopies against that predicted from these laboratory investigations.

KEY TO CODES:

AS	Australian STD 3567
DA	DEF/AUST 184
SO	Results on M Original ex MRL
MO	Results on M Original ex MRL
WO	Weatherometer (time/hours)
T	Temperate site Melbourne
SC	S Canvas ex Cloncurry – Hot-Dry
MC	M Canvas ex Cloncurry – Hot-Dry
SHW	S Canvas ex Innisfail – Hot-Wet Cleared
MHW	M Canvas ex Innisfail – Hot-Wet Cleared
SJ	S Canvas ex Innisfail – Hot-Wet Jungle
MJ	M Canvas ex Innisfail – Hot-Wet Jungle

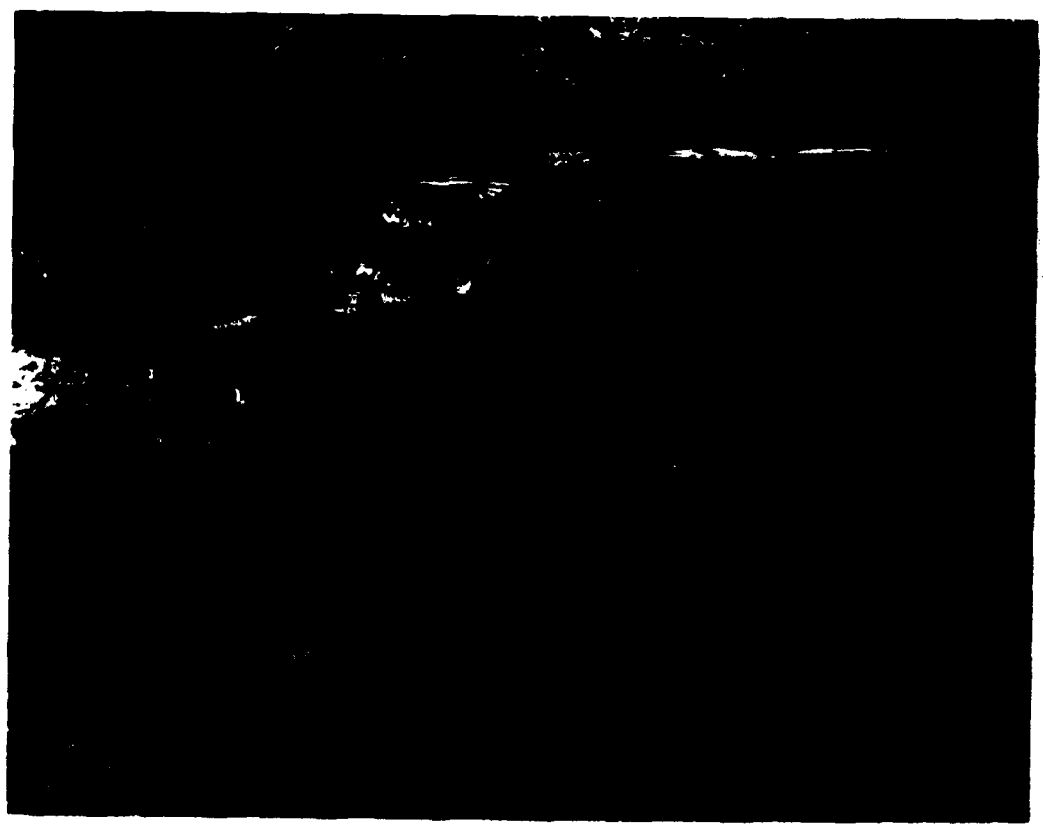


Figure 1: *Printed Pattern Canvas on "Perentie" Vehicle.*

2. Experimental

Canvas fabrics manufactured to AS 3567-1988, Textiles – Cloth Duck-Cotton and Polyester/Cotton [1] or DEF(AUST) 184, Cloth Duck-Cotton/Polyester, Corespun [2] specifications and printed in the designated camouflage design were supplied by two local manufacturers. These fabrics were of nominal loomstate mass 360 gm^2 and nominal proofed mass 500 gm^2. In general, the tests were performed as defined in either of the above specifications. To assist in identification the canvas materials were labelled "S" and "M". These camouflage printed corespun ducks were exposed under the following natural climatic conditions:

- Temperate site at MRL Melbourne, Victoria
- Tropical, Hot-Wet, Jungle site at MRL Queensland, Innisfail
- Tropical, Hot-Wet, Cleared site at MRL Queensland, Innisfail
- Tropical, Hot-Dry site at Cloncurry, Queensland.

The trial duration was twelve months and samples were withdrawn at three monthly intervals. Meteorological summaries for the "Tropical Hot-Wet, Cleared" site and the "Tropical, Hot-Dry" site used in the trial are contained in Appendix B. No climatic data was recorded for the other two sites.

In addition, the fabrics were exposed in an Atlas Weatherometer, model 60/DMC-R using a carbon arc and operating to a weathering cycle consisting of 3.8 h of light followed by 1 h of light and water spray. Samples were withdrawn from this artificial exposure after 110 h and 500 h.

Unexposed samples, as well as samples exposed to both the natural and artificial climatic conditions stated above, were evaluated for all or some of the following properties:

- breaking force,
- tearing strength,
- water resistance (hydrostatic head),
- water resistance (cone test),
- pH of aqueous extract,
- microbial growth after tropical exposure, and
- colour fastness.

3. Results and Discussion

3.1 Breaking Force

The breaking force of the fabric samples was assessed and the results are summarized in Table 1 and illustrated in Figure 2. A summary of the effects of exposure on the breaking force are given below.

Table 1: *Summary of the effects of exposure on the breaking force of test fabrics "S" and "M"*

Site	Retained Tensile Strength (%) 12 months exposure			
	Fabric "S"		Fabric "M"	
	Warp	Weft	Warp	Weft
Temperate, Melbourne	48	91	61	86
Tropical, Hot-Dry, Cloncurry	44	64	34	41
Tropical, Hot-Wet, Cleared Innisfail	47	63	36	43
Tropical, Hot-Wet, Jungle Innisfail	96	105	81	111
Weatherometer Exposures				
110 h	91	105	95	101
500 h	74	104	82	97

Note: Considerable strength losses of both the "M" and "S" fabrics occurred at the Tropical, Hot-Dry and Tropical, Hot-Wet, Cleared sites. Such losses were attributed to actinic degradation and to a lesser degree to reductions in fabric pH, which can result in acid damage to the cotton component of the corespun yarn. Leaching of the acid donor pentachlorophenol laurate (PCPL) occurs at the Innisfail Hot-Wet, Cleared site, due to rainfall and humidity.

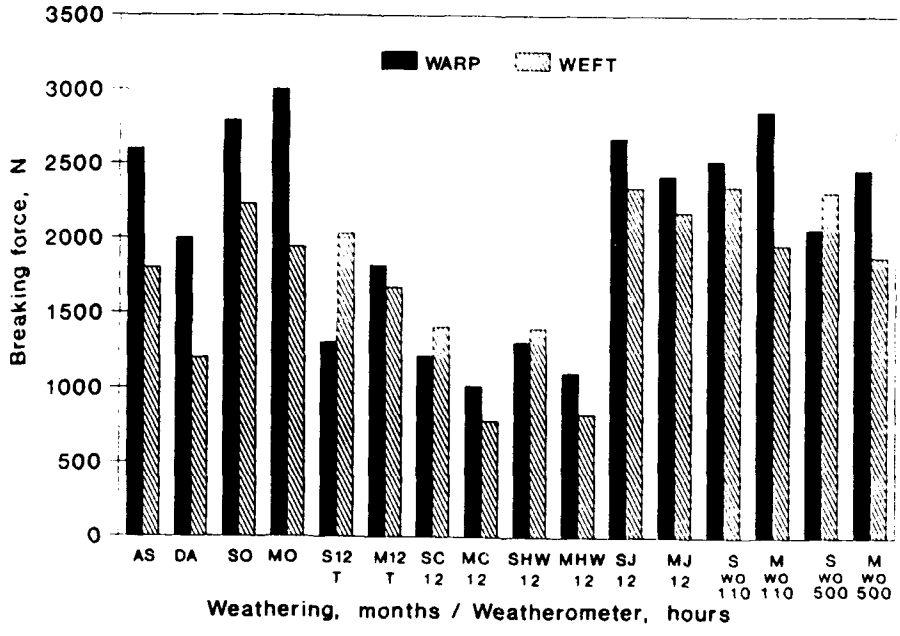


Figure 2: *Breaking Force Camouflage Canvas "S" vs "M".*

3.2 *Tearing Strength*

The tearing strength of the fabrics was determined by the "Wing Rip" method, which is a requirement of the DEF(AUST) 184 [2] and the AS 3567 [1] specifications. Detailed results are illustrated in Figure 3 and a summary of the changes in this property is given in Table 2.

Table 2: *Summary of the effects of exposure on the tearing strength of test fabrics "S" and "M"*

Site	Retained Tearing Strength (%) 12 months exposure			
	Fabric "S"		Fabric "M"	
	Warp	Weft	Warp	Weft
Temperate, Melbourne	70	78	43	75
Tropical, Hot-Dry, Cloncurry	50	64	50	63
Tropical, Hot-Wet, Cleared Innisfail	53	64	44	56
Tropical, Hot-Wet, Jungle Innisfail	88	95	84	90
Weatherometer Exposures				
110 h	102	106	93	95
500 h	100	81	93	89

Note: Considerable strength losses of both the "M" and "S" fabrics occurred at the Tropical, Hot-Dry and Tropical, Hot-Wet, Cleared sites. Such losses were attributed to actinic degradation and to a lesser degree to reductions in fabric pH, which can result in acid damage to the cotton component of the corespun yarn. Leaching of the acid donor pentachlorophenol laurate (PCPL) occurs at the Innisfail Hot-Wet, Cleared site, due to rainfall and humidity.

3.3 *Water Resistance*

Water resistance of the fabrics was determined by both the "Hydrostatic Head" method, which is a requirement of the DEF(AUST) 184 [2] and the AS 3567 [1] specifications, and the "Cone Test", which is only specified in AS 3567 [1]. Details of the results of these tests are provided in Figures 4 to 8.

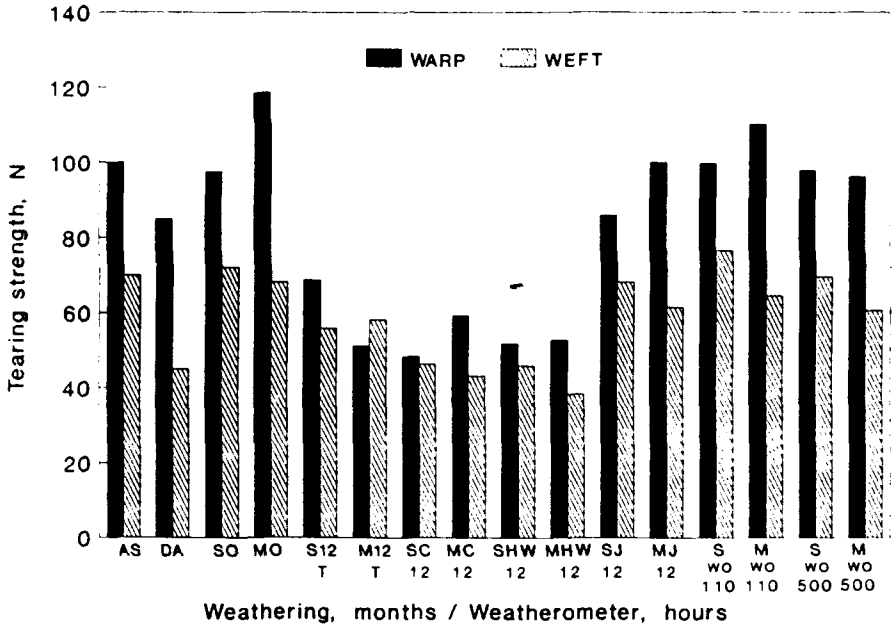


Figure 3: Tearing Strength (Wing Rip) Camouflage Canvas "S" vs "M".

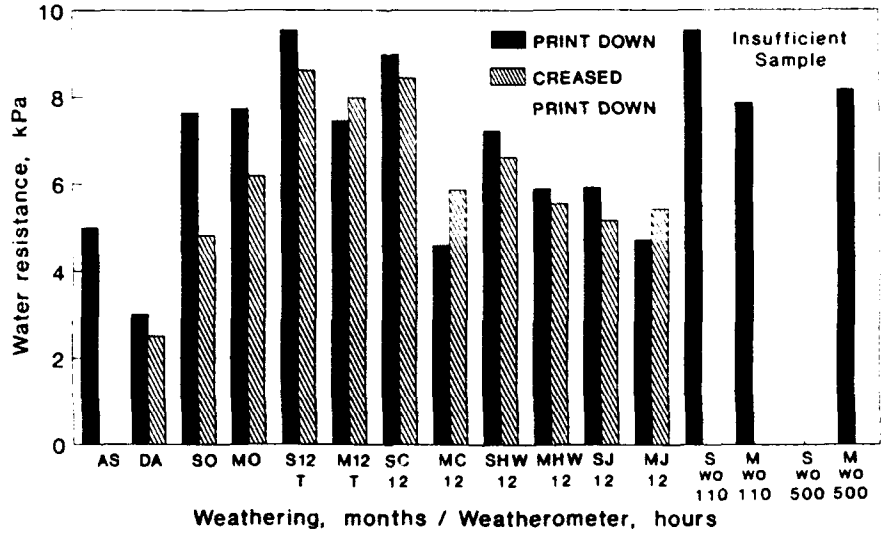


Figure 4: *Hydrostatic Head (Water Resistance) Camouflage Canvas "S" vs "M".*

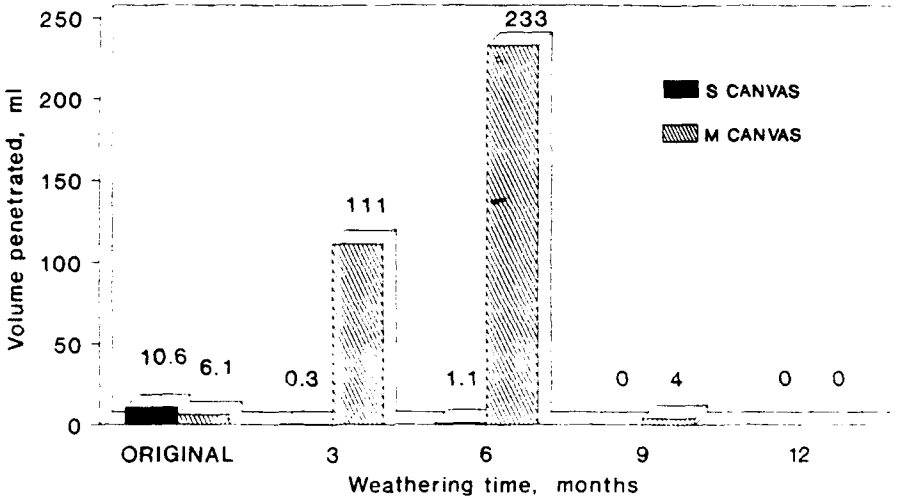


Figure 5: Cone Test Water Resistance, Volume Penetrated (ml) measured after various exposure durations at the Temperate Site, Melbourne.

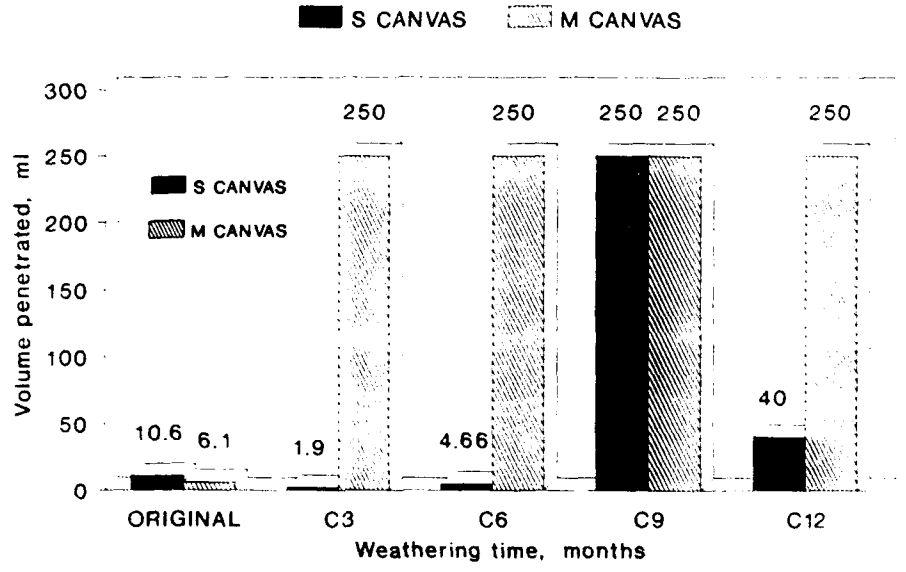


Figure 6: Cone Test, Tropical, Hot-Dry, Cloncurry Exposure Camouflage Canvas "S" vs "M".

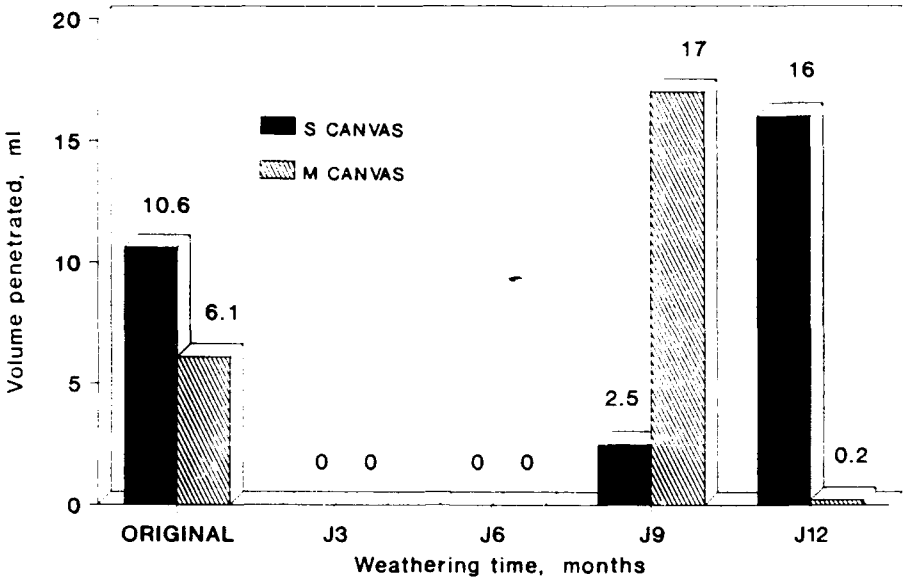


Figure 7: Cone Test, Tropical, Hot-Wet, Jungle, Innisfail, Exposure Camouflage Canvas "S" vs "M".

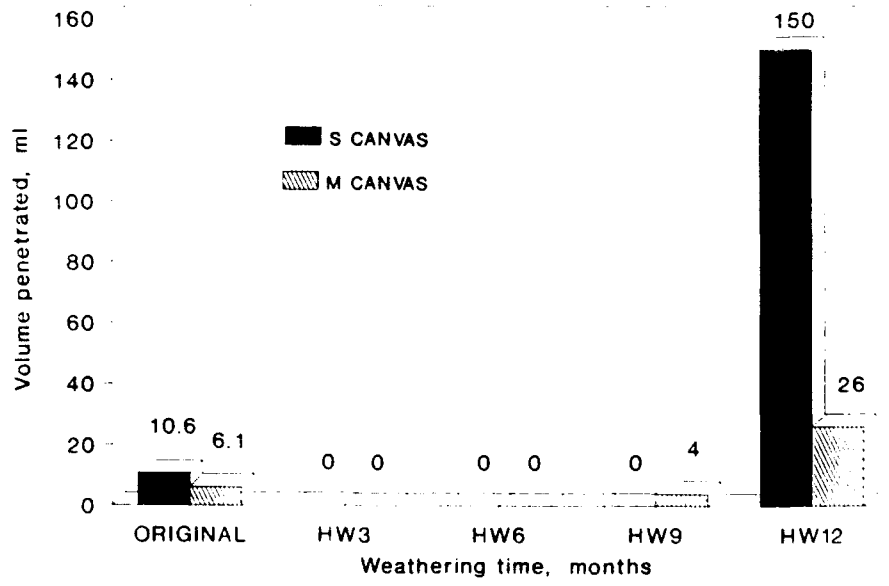


Figure 8: Cone Test, Tropical, Hot-Wet, Cleared Innisfail, Exposure Camouflage Canvas "S" vs "M".

Hydrostatic Head:

The AS 3567 [1] requirement for new cloth is a minimum of 5 kPa whereas the DEF(AUST) 184 [2] requirement for new cloth is 3 kPa initially and 2.5 kPa for creased fabric. All specimens met the DEF(AUST) 184 [2] requirements both before and after exposure at all sites. Samples designated by "M" dropped approximately 10% below the AS 3567 [1] requirement after 9 and 12 months exposure at the Tropical Hot-Wet, Jungle and Tropical Hot-Dry, Cloncurry sites. The water resistance of other samples increased with an increase in exposure time. This increase may have resulted from fabric shrinkage which reduced the interstitial spacings within the fabric weave and increased the fabric density. This suggestion was supported by an increase in mass and end and pick counts.

Cone Test:

AS 3561 [1] requires that the cone leakage shall be zero.

Results from this evaluation demonstrated the variability in the uniformity of the proofing systems used. It was also evident that printing caused a reduction in water resistance due to the wetting effect of the print paste.

3.4 pH

The pH requirements on new fabrics is within the range 5.0 to 9.0. Details of the pH measurements taken on the exposed material are given in Figure 9.

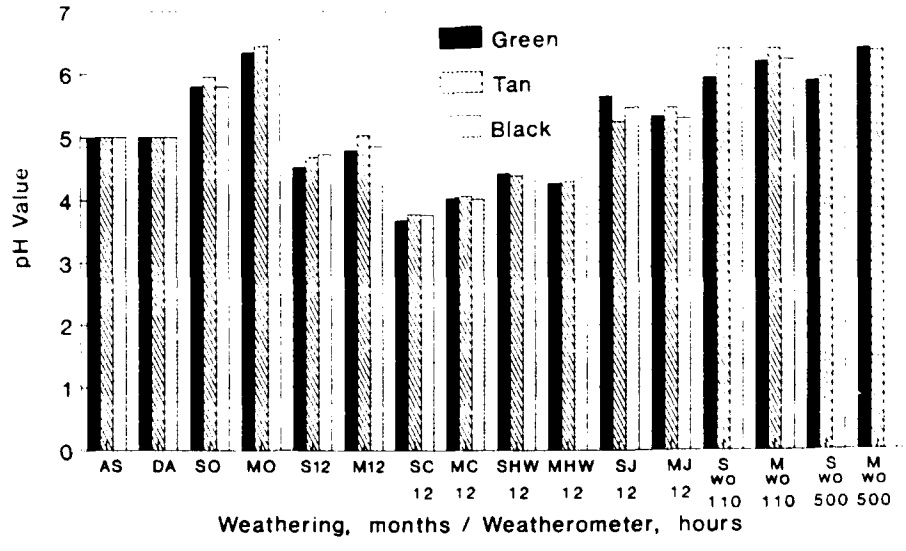


Figure 9: *pH Value, Camouflage Canvas "S" vs "M".*

After twelve months exposure at the Tropical, Hot-Wet, jungle site both "S" and "M" fabrics were virtually unaffected. The other natural weathering results ranged between pH 3.5 and pH 5.0 indicating increasing acidity. This is not unusual when products such as pentachlorophenol laurate are used as fungal resist agents. This product may also contribute to strength losses.

3.5 Colour

Colour changes were determined using the standard test methods required by the fabric specifications and are detailed in Appendix C. Notes on the changes in colour which occurred during natural exposure are as follows:

Tan: The tan colour retained its hue only when protected by the jungle canopy. In all other situations it faded to grey. To combat this shade change during fading, MRL has recommended that the tan colour be reformulated using inorganic pigments to replace the light sensitive organic pigments originally used.

Green: The olive green darkened somewhat except at Tropical, Hot-Dry site where it developed a brown hue. This was considered to be due mainly to the oxidation of chemicals used for rot resist. This finding is not peculiar to this exercise and has been tolerated for many years.

Black: The black remained black but varied in tone and flatness.

3.6 Fungal Growth

The degree of fungal growth was evaluated for fabrics exposed at the tropical sites and the results are detailed in Appendix D.

Surface fungal growth was evident on only the "S" samples at both the Jungle and Hot-Wet Cleared sites being first recorded for the three month withdrawal. A problem during production was identified as a probable cause and it is expected that this effect will be avoided in future.

4. Conclusions

Exposure trials have been completed on two commercially produced disruptively patterned printed canvases for Army vehicles.

Considerable strength losses on both fabrics occurred at the Tropical, Hot-Dry site, Cloncurry and the Tropical, Hot-Wet, Cleared site, Innisfail. Such losses were attributed to actinic degradation and to a lesser degree to acid damage of the corespun yarn.

Water resistance generally increased over time. This was attributed to fabric shrinkage as indicated in the increase in the number of ends and picks. The inclusion of the Cone Test demonstrated variability in proofing systems used and the effect of

printing, which reduced the water resistance due to the wetting effect of the print paste.

The colour fastness of the tan pigment requires improvement. At the commencement of the study reproofing paints were produced for use when refurbishing of canopies was required. A deteriorated vehicle canopy which was painted remained serviceable for another three years and the colours were still clearly distinguishable as black, tan or green. It is therefore suggested that for vehicles that have been fitted with the printed canvas and where the tan has faded badly in use, colour could be restored.

Army fitted some vehicles (Perentie) with the canvas type used in this trial with the intention to run a user trial in conjunction with the durability trial. Evaluation of the field trial will be the subject of a future report.

Since the commencement of this work the specification DEF(AUST) 184, Cloth, Duck-Cotton/Polyester, Corespun [2], which has been in existence since 1965 has been withdrawn and replaced by Australian Standard 3567 [1]. The fabrics used in this current task have been compared to the requirements of both the above mentioned specifications. New fabrics would substantially conform to the requirements of either specification, but canopies made from fabric conforming to the Australian Standard would be approximately 12 to 17% heavier than supplies previously purchased against the DEF(AUST) 184 [2] specification.

5. *Acknowledgements*

We are grateful for the assistance of the following for participating in this exercise: Staff of Paints Section, Textiles Technology, Optics and Mycology at MRL, two Australian canvas manufacturers and of DSTO MRL Qld.

6. *References*

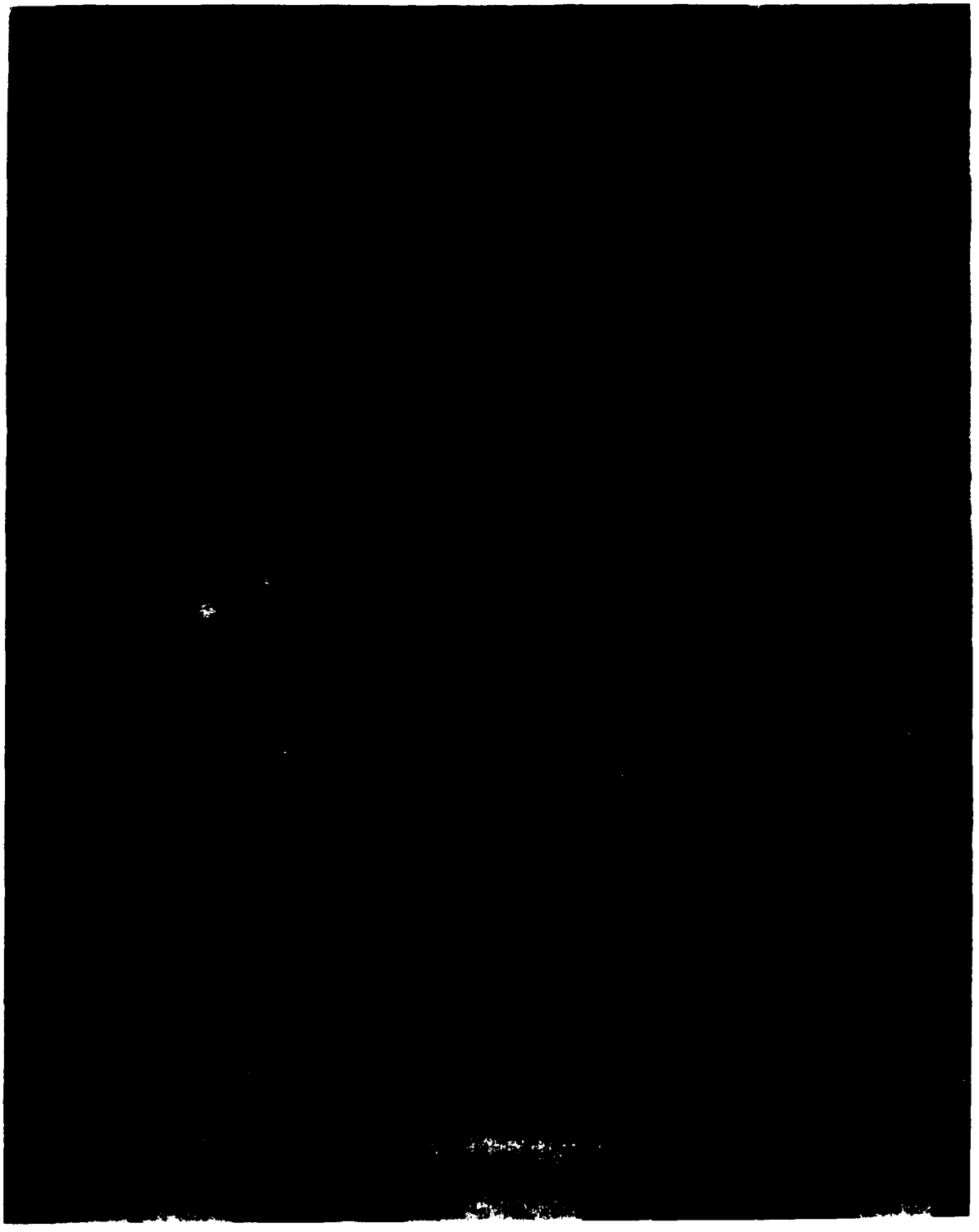
1. AS 3567-1988, Textiles – Cloth, Duck - Cotton and Polyester/Cotton.

2. DEF(AUST) 184, Cloth Duck-Cotton/Polyester, Corespun.

3. DEF(AUST) 5037, Methods of Test for Textile Materials.

Appendix A

Colour Separation Design for Printing Screens



Appendix B

Materials Research Laboratory DSTO (Queensland)
Meteorological Summary – Tropical, Hot-Wet, Cleared Site Innisfail

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT[1]	NOV	DEC	1989 YEAR	1990 JAN
TEMPERATURE (°C)														
Highest daily maximum	34.9	34.2	31.3	32.3	28.3	27.8	26.8	27.9	34.6	34.0	31.4	34.5	34.9	34.8
Average daily maximum	30.8	30.8	29.1	28.4	26.4	23.4	23.4	24.5	27.6	30.1	29.4	30.3	27.8	30.9
Average daily mean	26.2	26.2	25.4	24.3	22.9	19.6	19.7	19.9	21.9	24.6	25.3	25.5	23.5	26.2
Average daily minimum	23.0	22.8	22.8	21.6	20.6	16.6	17.0	16.2	17.3	20.1	22.2	21.6	20.1	22.5
Lowest daily minimum	20.6	19.6	21.2	17.0	17.5	10.7	10.6	11.0	14.9	16.3	20.5	19.6	10.6	19.9
RELATIVE HUMIDITY %														
Highest daily maximum	98	99	100	100	99	98	99	99	98	98	99	98	100	98
Average daily maximum	96	96	97	97	97	95	95	94	95	95	95	96	96	96
Average daily mean	82	82	88	86	87	82	84	78	76	75	81	78	82	79
Average daily minimum	60	58	69	64	71	61	65	55	47	48	59	55	59	56
Lowest daily minimum	42	35	52	34	50	38	35	23	21	25	40	27	21	27
% of time above 90% RH	47.1	41.1	61.2	57.8	57.4	36.7	46.9	32.3	28.3	25.6	41.3	34.9	42.5	37.7
% of time above 70% RH	76.9	76.7	89.3	88.8	90.8	82.4	85.1	72.9	67.4	61.2	75.6	66.7	77.8	69.7
% of time below 60% RH	6.3	8.0	1.3	3.9	1.8	10.0	8.6	14.1	20.8	24.3	10.0	13.6	10.2	12.2
PRECIPITATION														
Total rainfall (mm)	420.5	188.5	704.0	641.0	561.0	99.0	103.5	29.5	15.0	73.0	554.5	175.5	3565.0	109.5
Highest daily rainfall (mm)	102.5	72.0	166.5	127.0	188.5	40.5	30.0	13.0	5.5	62.5	179.0	88.0	188.5	52.5
Number of rain days	18	16	25	25	24	12	17	7	7	4	17	12	184	13
Duration of rainfall (hours)	42.3	27.3	74.8	85.7	76.5	22.7	27.5	6.8	4.3	5.7	64.8	29.5	468.0	19.3
RADIATION														
Total sun hours	176.8	182.2	92.0	71.5	72.2	110.7	103.4	159.6	199.5	228.1	169.7	245.6	1711.2	220.2
Total Global Horizontal (kWh/m^2)	167.4	156.1	115.3	102.9	90.8	90.3	86.1	120.3	147.2	172.8	147.0	192.6	1588.8	183.1
Total UV (kWh/m^2)	9.0	8.3	6.5	5.7	4.9	4.6	4.4	5.7	6.8	8.3	8.5	10.3	83.0	9.9

[1] OCT 14th 07:00 - 15th 02:50 data missing due to equipment failure

Appendix B (continued)

Materials Research Laboratory DSTO (Queensland)
Meteorological Summary – Tropical, Hot-Dry, Site at Cloncurry

	JAN	FEB	MAR	APR	MAY[1]	JUN[2]	JUL[3]	AUG	SEP	OCT	NOV	DEC[4]	1989 YEAR	1990 JAN
TEMPERATURE (°C)														
Highest daily maximum	38.4	37.7	34.9	33.3	31.3	29.4	28.6	33.6	35.4	36.6	36.8	36.2	38.4	40.0
Average daily maximum	35.8	34.2	32.0	30.5	27.4	22.3	22.7	24.5	30.4	33.8	32.1	32.9	29.9	36.2
Average daily mean	31.3	29.3	27.7	26.1	23.3	16.6	17.2	17.8	24.1	27.8	27.1	28.4	24.7	31.7
Average daily minimum	26.0	23.5	23.4	21.6	18.7	11.0	11.6	10.7	17.0	21.1	21.5	23.0	19.1	25.9
Lowest daily minimum	21.9	19.6	20.1	16.6	12.8	5.7	4.2	6.4	10.2	14.2	18.1	19.6	4.2	21.4
RELATIVE HUMIDITY %														
Highest daily maximum	100	100	100	100	100	100	100	62	75	97	100	99	100	100
Average daily maximum	75	80	91	78	76	69	69	39	38	49	59	71	66	77
Average daily mean	61	62	78	61	55	50	47	22	19	28	45	47	48	57
Average daily minimum	51	48	66	47	39	34	32	9	8	14	32	29	34	44
Lowest daily minimum	41	34	53	20	23	23	12	0	4	5	6	10	0	16
% of time above 70% RH	19.3	26.3	67.8	34.4	26.1	9.7	8.7	0.0	0.2	4.4	27.3	17.3	20.1	30.4
% of time below 60% RH	46.2	52.0	4.2	37.2	55.8	75.1	81.1	99.0	99.7	94.3	71.8	69.4	65.5	60.4
PRECIPITATION														
Total rainfall (mm)	1.5	42.5	60.5	19.3	13.5	6.3	6.8	0.0	0.0	52.8	106.8	78.3	388.0	23.8
Highest daily rainfall (mm)	1.5	33.5	27.5	18.3	10.0	3.8	6.3	0.0	0.0	37.3	57.0	55.5	57.0	19.0
Number of rain days	1	8	10	3	3	2	2	0	0	2	6	5	42	2
Duration of rainfall (hours)	0.3	7.3	11.3	3.2	4.2	3.2	3.2	0.0	0.0	6.7	12.0	10.2	61.5	0.8
RADIATION														
Total sun hours	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Global Horizontal (kWh/m^2)	231.9	194.0	179.9	158.8	135.1	130.7	131.7	180.0	195.4	215.6	209.3	170.6	2133.0	197.1
Total UV (kWh/m^2)	10.4	8.7	8.4	7.2	5.9	5.4	5.7	7.6	8.0	9.0	9.3	7.1	92.6	8.0

[1] MAY – 7th 06:20 - 8th 08:50 data missing due to equipment failure.
[2] JUN – 22nd 06:30 - 23rd 08:20 data missing due to equipment failure.
[3] JUL – 2nd 06:40 - 3rd 09:40 data missing due to equipment failure.
[4] DEC – 8th 16:20 - 12th 09:50, 15th 05:40 - 18th 06:50 and 26th 05:40 - 28th 07:00 data missing due to equipment failure.

Appendix C

Camouflage Printed Canvas "S" vs "M", as received. Colour Fastness

Type of Test	Colour	Requirement AS	Requirement DA	Results Original S	Results Original M	Results Weatherometer S110	Results Weatherometer M110
Colour Fastness to Light: MBTF Lamp	green	Min. 6	Min. 7	60 DK	60 DK	-	-
	tan	open to		6-7	6-7	-	-
	black	negotiation		60 DK	60 DK	-	-
Colour Fastness to Light: Daylight (under glass)	green	Min. 6	Min. 7	6-7	6-7	-	-
	tan	open to		6-7	6-7	-	-
	black	negotiation		6-7	6-7	-	-
Colour Fastness to Weatherometer:	No change						
	green			-	-	3-40 DK	30 DK
	tan			-	-	4	4
	black			-	-	3-40 DK	30 DK
Colour Fastness to Rubbing:							
	Print						
Dry rubbing:	Print						
	green		Min. 3	3	2	-	
	tan			3	3-4	-	-
	black			3	2	-	-
Wet rubbing:	green		Min. 3	2-3	3	-	-
	tan			2-3	3-4	-	-
	black			2-3	2-3	-	-

CODE:

AS	Australian Standard 3567
DA	Def Aust. Standard 184
S110	Canvas S 110 hrs Weatherometer
M110	Canvas M 110 hrs Weatherometer
DK	Darker

Appendix D

Assessment of Canvas Fabrics for Microbial Growth after Tropical Exposure, according to AS 1175 Part 2

Colour	SO	MO	S	M	S	M	S	M	S	M
			3 months	3 months	6 months	6 months	9 months	9 months	12 months	12 months
Tropical, Hot-Wet, Cleared Innisfail										
green	0	0	2#	0	3	0	3	0	3#	0
tan	0	0	1#	9	3	1	3	9	3#	0
black	0	0	1#	0	3	0	3	0	3#	0
reverse	0	0	1#	0	2	0	2	0	2#	0
Tropical, Hot-Wet, Jungle, Innisfail										
green	0	0	1+	0	2	1"	1	1"	3+	1*
tan	0	0	1+	0	2	1"	1	1"	3+	1*
black	0	0	1+	0	2	1"	1	1"	3+	1*
reverse	0	0	1+	0	1	1"	1	1"	3+	1*
Tropical, Hot-Dry, Cloncurry										
green	0	0	0	0	0	0	0	0	0	0
tan	0	0	0	0	0	0	0	0	0	0
black	0	0	0	0	0	0	0	0	0	0
reverse	0	0	0	0	0	0	0	0	0	0

CODE:

0-5 Fungi assessed on 0-5 scale in which 0 no growth, 5 total cover of heavy growth.

* Fungi mostly associated with surface deposits. Green algae also present on these specimens.

\# Cladosporium.

\+ Several genera of fungi.

" Growth on surface deposits.

COMMENTS:

1. Absence of fungi on samples exposed at Cloncurry only indicates climatic conditions not favouring growth (too dry).

2. Early appearance of fungi on "S" specimens exposed HW Innisfail becoming more dense than in the jungle (6 to 9 months) indicates U-V sensitive fungicide.

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TITLE

Disruptive pattern printed canvas for army vehicles

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ANNOUNCEMENT

Announcement of this report is unlimited

KEYWORDS

Print Durability	Climatic Testing	Colour Fastness
Fabric Properties	Tensile Strength	Tearing Force

ABSTRACT

A design for the disruptive pattern printing of canvas used for canopies on army vehicles was developed by DSTO MRL Melbourne. The effect of exposure to a variety of climatic conditions on print durability and fabric properties was determined.